FERMILAB-Conf-04/214-E September 2004

DØ Note 4599
FERMILAB-CONF-04-214-E

Search for GMSB SUSY in Diphoton Events with Large Missing ET[a]

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ABSTRACT

Results on a search for GMSB SUSY in the diphoton final state using data collected by the DØ experiment at the Fermilab Tevatron (Run II) are reported. No excess of events above the standard model background has been found, and lower limits on the lightest chargino and neutralino masses have been set. These are the most stringent to date in the class of models considered in this analysis.

1. Introduction

One of the possible scenarios to break supersymmetry (SUSY) is gauge mediated supersymmetry breaking (GMSB), originally proposed in Ref. [1]. In GMSB models, SUSY breaking is propagated from the hidden sector to SUSY particles through gauge interactions via new messenger fields, at a scale $\Lambda \ll \mathrm{M_{Planck}}$. The minimal set of parameters necessary to describe GMSB models consists of the effective scale of SUSY breaking Λ, the messenger mass scale M_m, the number of messenger fields N_5, the ratio of the vacuum expectation values of the Higgs fields $\tan\beta$ and the sign of the Higgsino mass term μ. The phenomenology of these models is very different from that of gravity-mediated SUSY models.

In GMSB models, the gravitino is the lightest supersymmetric particle (LSP), with a mass less than about 1 keV. The phenomenology of those models is therefore determined by the next-to-lightest supersymmetric particle (NLSP), which can be either a neutralino or a slepton. In the case considered in this analysis, the NLSP is a neutralino and decays into a photon and the LSP (a gravitino).

The model considered has only one parameter Λ, with $M_m = 2\Lambda$, $N_5 = 1$, $\tan\beta = 5$ and $\mu > 0$. The lifetime of the neutralino is not fixed by the model and is assumed to be short enough for the NLSP to decay close to the interaction point. Assuming that R-parity is conserved, SUSY particles are pair-produced, their decay leads to two NLSPs and the signal of interest is a final state with two photons and large missing transverse energy ($\not\!\!E_T$). Current lower limits on the GMSB neutralino mass are 65, 75 and 100 GeV from the CDF [2], DØ [3] and LEP collaborations [4].

[a]Talk presented at the 12$^{\mathrm{th}}$ International Conference on Suypersymmetry and Unification of Fundamental Interactions (SUSY04), June 17-23, 2004, in Tsukuba, Japan. To appear in the proceedings.

The analysis reported here was performed with the DØ detector in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV at the Fermilab Tevatron Collider. The detector comprises a central tracking system in a 2 T superconducting solenoidal magnet, a liquid-argon/uranium calorimeter, and a muon spectrometer [5]. The tracking system consists of a silicon microstrip tracker and a scintillating fibre tracker and provides coverage for charged particles in the pseudorapidity range $|\eta| < 3$. The calorimeters are finely segmented and consist of a central section (CC) covering $|\eta| \leq 1.1$, and two end calorimeters (EC) extending coverage to $|\eta| \approx 4$, all housed in separate cryostats [6]. The electromagnetic (EM) section of the calorimeter has four longitudinal layers and transverse segmentation of 0.1×0.1 in $\eta - \phi$ space (where ϕ is the azimuthal angle), except in the third layer, corresponding to EM shower maximum, where it is 0.05×0.05.

The data sample was collected between April 2002 and October 2003. The integrated luminosity is 185 pb^{-1}.

2. Event Selection

Considered events were selected online with inclusive single electromagnetic and di-EM triggers. The trigger efficiency for events with two photons with transverse energy $E_T > 20$ GeV is 97±1%.

Electrons and photons consist of an EM cluster with or without a reconstructed track pointing to it, respectively. An electron has a track matched to the EM cluster while a photon does not. EM clusters must have most of their energy deposited in the EM section of the calorimeter, most of their energy in the core of the cluster, transverse and longitudinal shapes consistent with an EM shower, and satisfy a track isolation in a hollow cone around their centre. The di-EM identification efficiency was found to be 85.9±0.4% using $Z \to ee$ events. The efficiency of the track matching was estimated to be 94.2±0.3%.

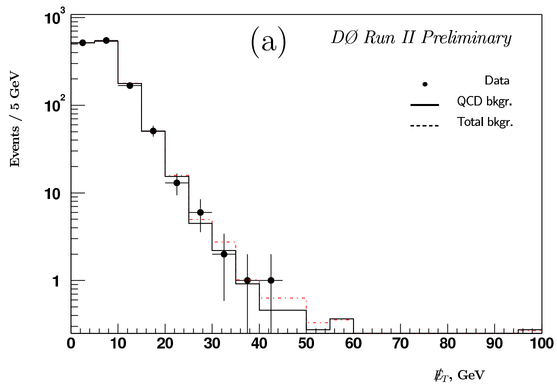
Missing transverse energy is determined from the energy deposited in the whole calorimeter and corrected for jet and EM energy scales. Jets are reconstructed using the iterative, midpoint cone algorithm [7] with a cone size of 0.5.

Events were required to have two photons in the CC, each with $E_T > 20$ GeV. To suppress events with mismeasured $\not\!\!E_T$, the azimuthal opening angle ($\Delta\phi$) between the direction of $\not\!\!E_T$ and the highest E_T jet (if any) should be less than 2.5 radians. Moreover the $\Delta\phi$ between the direction of $\not\!\!E_T$ and either photon should be at least 0.5 radian.

This selection yields 1308 events ($\gamma\gamma$ sample). The $\not\!\!E_T$ distribution of these events is shown in Fig. 1a. Event counts for different $\not\!\!E_T$ regions are shown in Table 1.

Table 1: Event counts in the $\gamma\gamma$ sample and contribution from the QCD and $e\gamma$ backgrounds.

$\not\!\!E_T$	<15 GeV	>30 GeV	>40 GeV	>50 GeV
$\gamma\gamma$ sample	1234	4	1	0
QCD contamination	100%	5.2 ± 0.7	2.1 ± 0.4	1.2 ± 0.3
$e\gamma$ contamination		0.9 ± 0.2	0.4 ± 0.1	0.1 ± 0.1
Total background		6.1 ± 0.7	2.5 ± 0.5	1.3 ± 0.3



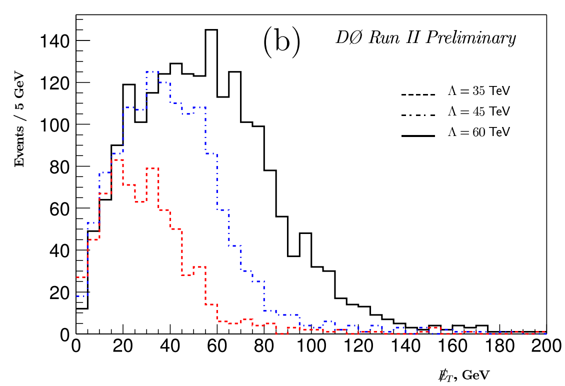


Figure 1: (a) $\not\!\!E_T$ distribution in the $\gamma\gamma$ sample (dots), QCD background (solid line) and total background (dashed line); (b) $\not\!\!E_T$ distribution for GMSB signal events with $\Lambda = 35$ TeV (dashed), $\Lambda = 45$ TeV (dotted-dashed) and $\Lambda = 60$ TeV (solid) (arbitrary normalisation).

3. Background Estimation

The main backgrounds arise from standard model processes with misidentified photons and electrons and/or mismeasured $\not\!\!E_T$. The background with no real $\not\!\!E_T$ includes QCD processes with direct photon production or jets misidentified as photons and Drell-Yan processes with electrons misreconstructed as photons due to tracking inefficiency. It was studied on a QCD sample derived from the same dataset using di-EM events that satisfy the same criteria as described in Section 2 but where the EM clusters fail the shower shape requirement. Those events have similar characteristics to the background in the $\gamma\gamma$ sample, so that the $\not\!\!E_T$ shape can be measured (see Fig. 1a). The sample contains 14324 events. Assuming that all events in the $\gamma\gamma$ sample with $\not\!\!E_T < 15$ GeV are QCD events, the QCD contamination of the $\gamma\gamma$ sample for higher $\not\!\!E_T$ can be extracted from this QCD sample (see Table 1).

The background from processes with genuine $\not\!\!E_T$ is dominated by $W(\rightarrow e\nu)$'γ' events where the electron is misidentified as a photon and 'γ' denotes either a real photon or a misidentified jet. There are also contributions from $W \rightarrow \tau\tau \rightarrow ee + X$ and $t\bar{t}, WW, WZ \rightarrow ee$+jets. This background was estimated on an $e\gamma$ sample built in the same way as in Section 2 but where one on the EM objects is required to have a matching track and satisfy an electron track isolation. It contains 608 events, mostly from QCD which is subtracted in the same way as in the $\gamma\gamma$ sample, so that the $e\gamma$ contamination of the $\gamma\gamma$ sample can be extracted using the probability for an electron to be misidentified as a photon (see Table 1). The track-matching efficiency was determined from Z events.

The $\not\!\!E_T$ distribution of the sum of the electron and QCD backgrounds is shown in Fig. 1a.

4. Limit Calculation

To estimate the expected signal for the model described in Section 1, Monte Carlo events were generated for several values of Λ. The dominant contributions to the cross section come from lightest chargino pair production ($\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp$) and lightest chargino-second lightest neutralino ($\tilde{\chi}_1^\pm \tilde{\chi}_2^0$) production (see Ref [8]). SUSY particle masses and couplings were determined with ISAJET 7.58 [9], and PYTHIA 6.202 [10] was used to generate the events and get the leading order cross sections. A K-factor was used to estimate the next-to-leading order cross section (from Ref. [8]). Events were processed through the full detector simulation and reconstruction, and analysed as the data. The $\not\!\!E_T$ distribution for different values of Λ are shown in Fig. 1b.

Since the observed number of events is in good agreement with the standard model expectation, there is no evidence of GMSB SUSY in the data. Upper limits on the production cross section were set using a Bayesian approach [11] with a flat prior. The selection $\not\!\!E_T > 40$ GeV gives the best expected limit and results are shown in Fig. 2. This translates into a 95% C.L. lower limit $\Lambda > 78.8$ TeV, corresponding to gaugino masses of $m_{\tilde{\chi}_1^0} > 105$ GeV and $m_{\tilde{\chi}_1^\pm} > 192$ GeV. These are the most restrictive limits to date for this class of model. An updated version of this analysis, using more data and several theoretical models (including the "Snowmass Slope") can be found in Ref. [12].

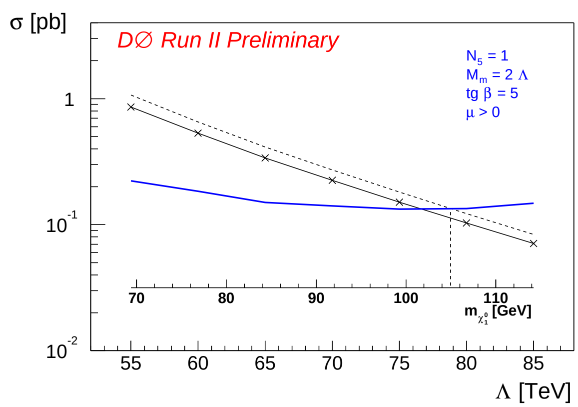


Figure 2: Predicted cross sections vs Λ in leading order (solid line with crosses), multiplied by the K-factor (dashed) and the 95% C.L. limits (solid). The model parameters are $M_m = 2\Lambda$, $N_5 = 1$, $\tan\beta = 5$ and $\mu > 0$

5. References

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